Low temperature GaAs solar cells produced by RP-VPE and PECVD

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To meet the increasing demand for high-efficiency photovoltaic (PV) technologies, alternatives to crystalline silicon (c-Si), now approaching its efficiency limit, must be explored. Among these, III-V semiconductors such as GaAs are good candidates as they offer excellent optical and electronic properties, including high electron mobility, direct and tunable bandgaps, and proven device efficiencies exceeding 30%[1]. However, their widespread adoption remains limited by their high production costs, largely due to expensive substrates (e.g., GaAs, Ge) and costly epitaxial growth methods such as MOCVD and MBE, which either require ultra-high vacuum or temperatures above 500°C[2].

In this work, we address the homoepitaxial growth of GaAs thin films using Remote Plasma Vapor Phase Epitaxy (RP-VPE) and their subsequent integration into a heterojunction (HJ) solar cell architecture. The RP-VPE process, operating at intermediate pressure (~0.5 mbar), enables epitaxial growth (Fig 1) at a significantly reduced thermal budget compared to conventional methods, maintaining reasonable growth rate of ~1.5µm/h[3].

Unlike standard GaAs homojunction solar cells (Fig.2a), our design replaces the top contact with hydrogenated amorphous silicon (a-Si:H) passivation layer and a nanocrystalline silicon oxide (nc-SiOx:H) emitter, both deposited via Plasma-Enhanced Chemical Vapor Deposition (PECVD) at temperature as low as 200°C (Fig.2b). This new architecture not only allows complete device fabrication at temperatures below 500 °C, but it also replaces the conventional emitter/window layers with a simplified Si-based stack.

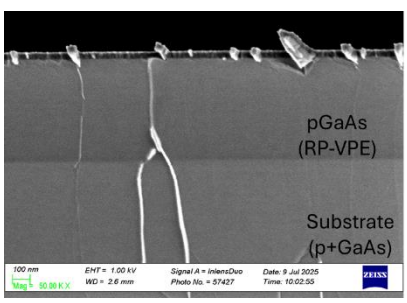

Fig 1: SEM cross section images of GaAs homoepitaxially grown.

In Fig.2(c), we compare the J(V) characteristics of the reference cell (a full III-V epitaxial structure based on a RP-VPE absorber), the newly proposed architecture, and a heterojunction device from IBM employing only an a-Si:H emitter on GaAs[4]. This comparison allows for a direct comparison between various configurations. We show that our new proposed architecture exhibits reasonable device performance, validating both the approach and the viability of low-temperature integration.

In conclusion, we demonstrate working GaAs-based devices. Ongoing developments, including improved surface passivation and in-situ doping, are expected to further enhance device performance toward levels achieved by conventional GaAs solar cells.

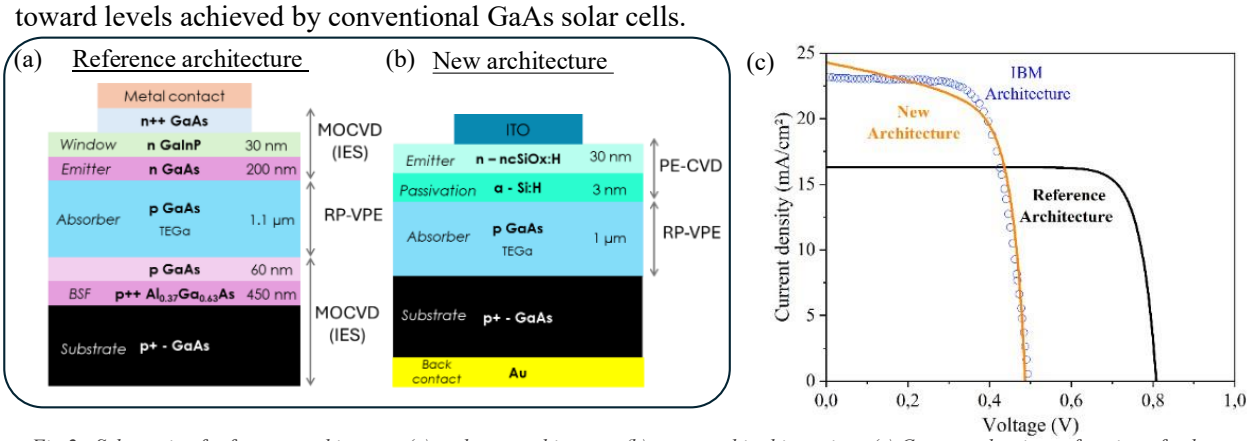

Fig 2: Schematic of reference architecture (a) and new architecture (b) presented in this project. (c) Currenty density as function of voltage under illumination of reference architecture, new architecture and and IBM architecture [4].

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[1] National Renewable Energy Laboratory (NREL). *Best Research-Cell Efficiency Chart*.

[2] Pelzel, R. A comparison of MOVPE and MBE Growth Technologies for III-V Epitaxial Structures; 2013.

[3] Watrin, L. et al. Homoepitaxial Growth of Device-Grade GaAs Using Low-Pressure Remote Plasma CVD. *Mater. Sci. Semicond Process.* **2025**, *186, 109069*

[4] Shahrjerdi, D. *et al.* Low-Temperature a-Si:H/GaAs Heterojunction Solar Cells. *IEEE J. Photovolt.* **2011**, *1* (1), 104–107